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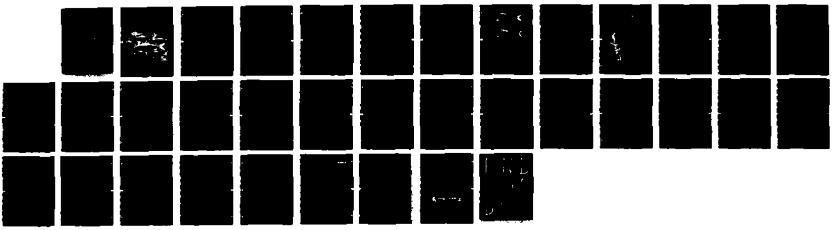

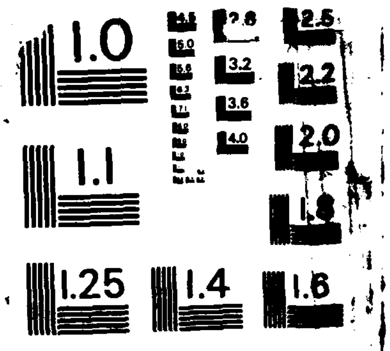


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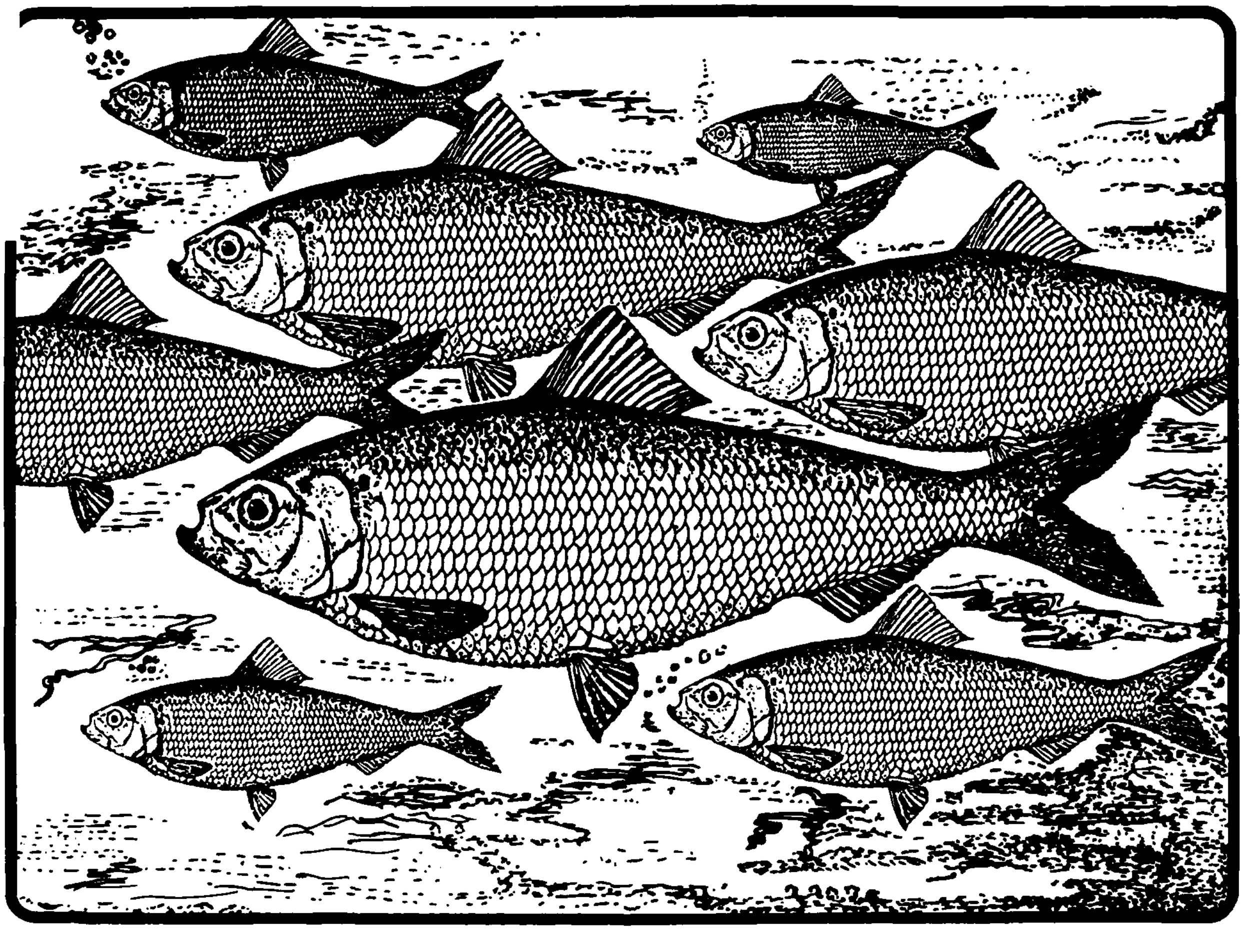
# Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

# ALEWIFE/BLUEBACK HERRING





Fish and Wildlife Service
**U.S. Department of the Interior**

Coastal Ecology Group
Waterways Experiment Station
**U.S. Army Corps of Engineers**

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October 1983

# Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

## ALEWIFE/BLUEBACK HERRING

by

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in cooperation with
Coastal Ecology Group
U.S. Army Corps of Engineers
Waterways Experiment Station

Performed for
National Coastal Ecosystems Team
Division of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

# CONVERSION FACTORS

## Metric to U.S. Customary

| Multiply | By | To Obtain |
|---|---|---|
| millimeters (mm) | 0.03937 | inches |
| centimeters (cm) | 0.3937 | inches |
| meters (m) | 3.281 | feet |
| kilometers (km) | 0.6214 | miles |
| square meters ($m^2$) | 10.76 | square feet |
| square kilometers ($km^2$) | 0.3861 | square miles |
| hectares (ha) | 2.471 | acres |
| liters (l) | 0.2642 | gallons |
| cubic meters ($m^3$) | 35.31 | cubic feet |
| cubic meters | 0.0008110 | acre-feet |
| milligrams (mg) | 0.00003527 | ounces |
| grams (gm) | 0.03527 | ounces |
| kilograms (kg) | 2.205 | pounds |
| metric tons (mt) | 2205.0 | pounds |
| metric tons (mt) | 1.102 | short tons |
| kilocalories (kcal) | 3.968 | BTU |
| Celsius degrees | 1.8(C°) + 32 | Fahrenheit degrees |

## U.S. Customary to Metric

| | | |
|---|---|---|
| inches | 25.40 | millimeters |
| inches | 2.54 | centimeters |
| feet (ft) | 0.3048 | meters |
| fathoms | 1.829 | meters |
| miles (mi) | 1.609 | kilometers |
| nautical miles (nmi) | 1.852 | kilometers |
| square feet ($ft^2$) | 0.0929 | square meters |
| acres | 0.4047 | hectares |
| square miles ($mi^2$) | 2.590 | square kilometers |
| gallons (gal) | 3.785 | liters |
| cubic feet ($ft^3$) | 0.02831 | cubic meters |
| acre-feet | 1233.0 | cubic meters |
| ounces (oz) | 28.35 | grams |
| pounds (lb) | 0.4536 | kilograms |
| short tons (ton) | 0.9072 | metric tons |
| BTU | 0.2520 | kilocalories |
| Fahrenheit degrees | 0.5556(F° - 32) | Celsius degrees |

## CONTENTS





A-1

# PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Habitat Suitability Index (HSI) models are being prepared by the U.S. Fish and Wildlife Service for the alewife and blueback herring. HSI models are designed to provide a numerical index of the relative value of a given site as fish or wildlife habitat.

Suggestions or questions regarding this report should be directed to:

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER
Post Office Box 631
Vicksburg, MS 39180

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11. U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- alewife/blueback herring. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.9. U.S. Army Corps of Engineers, TR EL-82-4. 25 pp.

## ACKNOWLEDGMENTS

We are grateful for the review by Dr. Joseph Loesch, Virginia Institute of Marine Science, Gloucester Point. We appreciate permission from the Canadian Journal of Fisheries and Aquatic Sciences for reprinting Figures 1 and 3. Permission is acknowledged from the Southeastern Association of Fish and Wildlife Agencies for reprinting Figure 4.

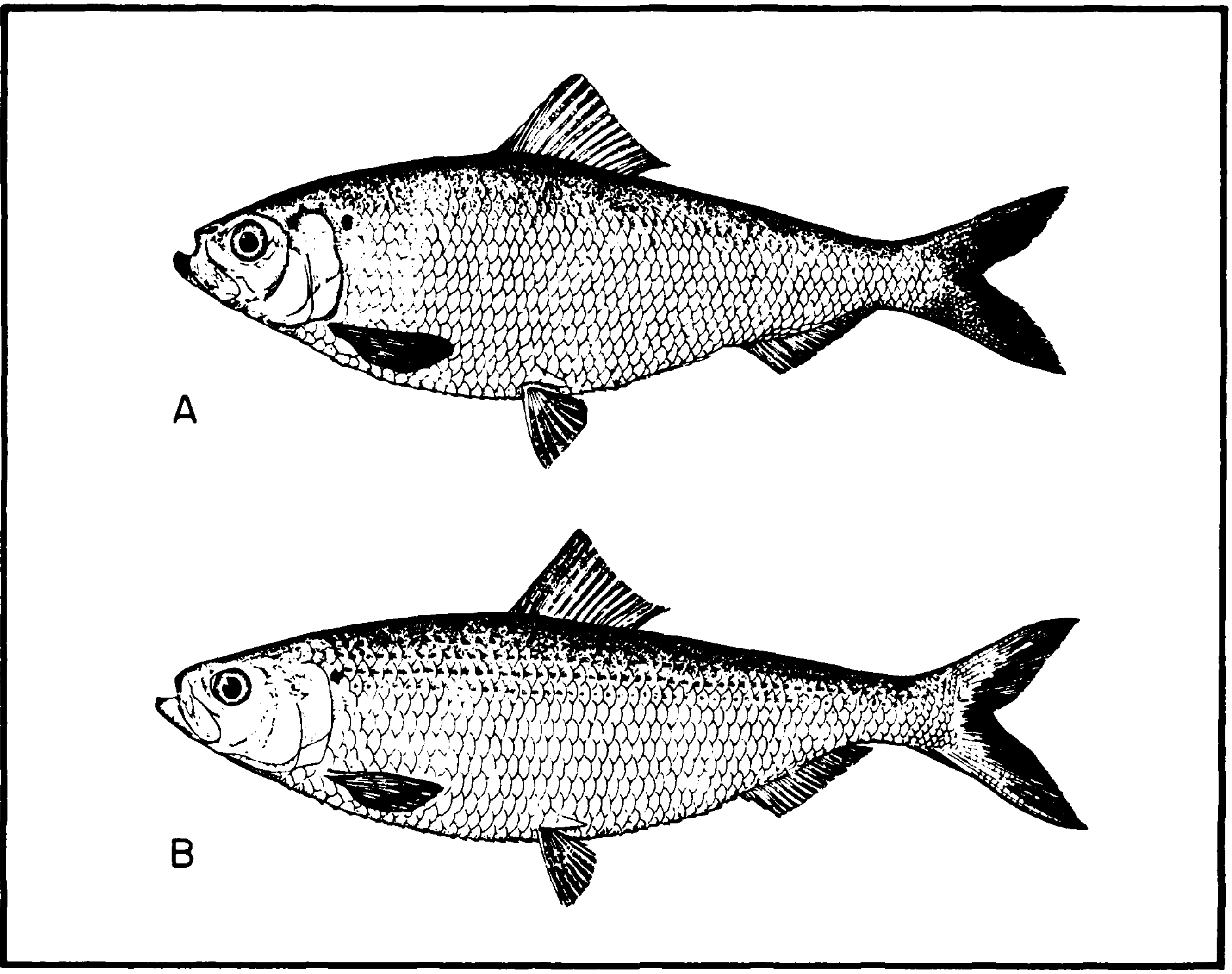


Figure 1. A: alewife; B: blueback herring.

# ALEWIFE/BLUEBACK HERRING

## PROFILE SCOPE

This profile covers life history and environmental requirements of both alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis), since their distribution is overlapping and their morphology, ecological role, and environmental requirements are similar. Nevertheless, significant differences in certain physical, physiological, and biological characteristics exist between the two species. When available, these differences are addressed by separate statements for each species. In addition, a special section on the most readily distinguishing characteristics for separating eggs, larvae, and adults of the two clupeids is presented in the morphology section of this profile.

Because most of the information available concerns the alewife, characteristics of this species are given priority reference in the text. Features should not be considered similar in the two species unless noted as such. In a few studies (particularly commercial fisheries statistics), the two species are referred to collectively as "river herring" or "gaspereau" (Canada).

## NOMENCLATURE/TAXONOMY/RANGE

Scientific names. .*Alosa pseudoharengus* (Wilson)/*Alosa aestivalis* (Mitchill)
Preferred common names. . Alewife/blueback herring (Figure 1)
Other common names. . . . River herring, gaspereau, oldwife.
Class . . . . . . . . . . . . . . . . . . . . . Osteichthyes
Order . . . . . . . . . . . . . . . . . . . . Clupeiformes
Family . . . . . . . . . . . . . . . . . . . . . . Clupeidae

Geographical range: The alewife is an anadromous species found in riverine, estuarine, and Atlantic coastal habitats, depending on life cycle stage, from Newfoundland (Winters et al. 1973) to South Carolina (Berry 1964). Landlocked populations are in the Great Lakes, Finger Lakes, and many other freshwater lakes (Bigelow and Schroeder 1953; Scott and Crossman 1973). The blueback herring is an anadromous species found in riverine, estuarine, and Atlantic coastal habitats, depending on life stage cycle, from Nova Scotia to the St. Johns River, Florida (Hildebrand 1963) (see Figure 2 for a map of the mid-Atlantic distribution of alewives and blueback herring).

## MORPHOLOGY/IDENTIFICATION AIDS

The following information was taken from summaries in Jones et al. (1978), unless otherwise indicated.

### Alewife

Dorsal rays 12-19 (usually 13-14), anal rays 15-21 (usually 17-18), scales in lateral series 42-54. Prepelvic scutes 17-21 (usually 19-20), postpelvic scutes 12-17 (usually 14-15), gill rakers on first arch 38-46. Body strongly compressed, deep. Mouth oblique, anterior end of lower jaw thick, heavy, and extending to middle of orbit. Eye large, diameter greater than snout length. Color: dorsally grey to grey-green, laterally silver with prominent dark shoulder spot; fins pale, yellow or green.

### Blueback Herring

Dorsal rays 15-20, anal rays 15-21, scales in lateral series 46-54. Prepelvic scutes 18-21, postpelvic scutes 12-16, gill rakers on first arch 41-52. Body moderately compressed, elongate, eye diameter small, equal to or less than snout length. Upper jaw with definitive median notch, no teeth on premaxillaries. Color: dorsally blue to blue-green, laterally silver with prominent dark shoulder spot; fins pale, yellow or green.

### Aids for Species Separation

Eggs. Unfertilized blueback herring eggs amber, alewife eggs green. Oil droplets of fertilized eggs unequal and scattered for blueback herring, numerous and uniformly tiny for alewife (Kuntz and Radcliffe 1917; Norden 1967).

Larvae. Myomeres between insertion of dorsal fin and anal vent 11-13 (mean 11.8) for blueback herring larvae, 7-9 (mean 8.0) for alewife larvae (this characteristic is definitive according to Chambers et al. 1976). Larvae less than approximately 15 mm[1] can be separated using regressions of vent to tail distance (mm) and vent to urostyle distance (mm), against

[1] 25.4 mm = 1 inch.

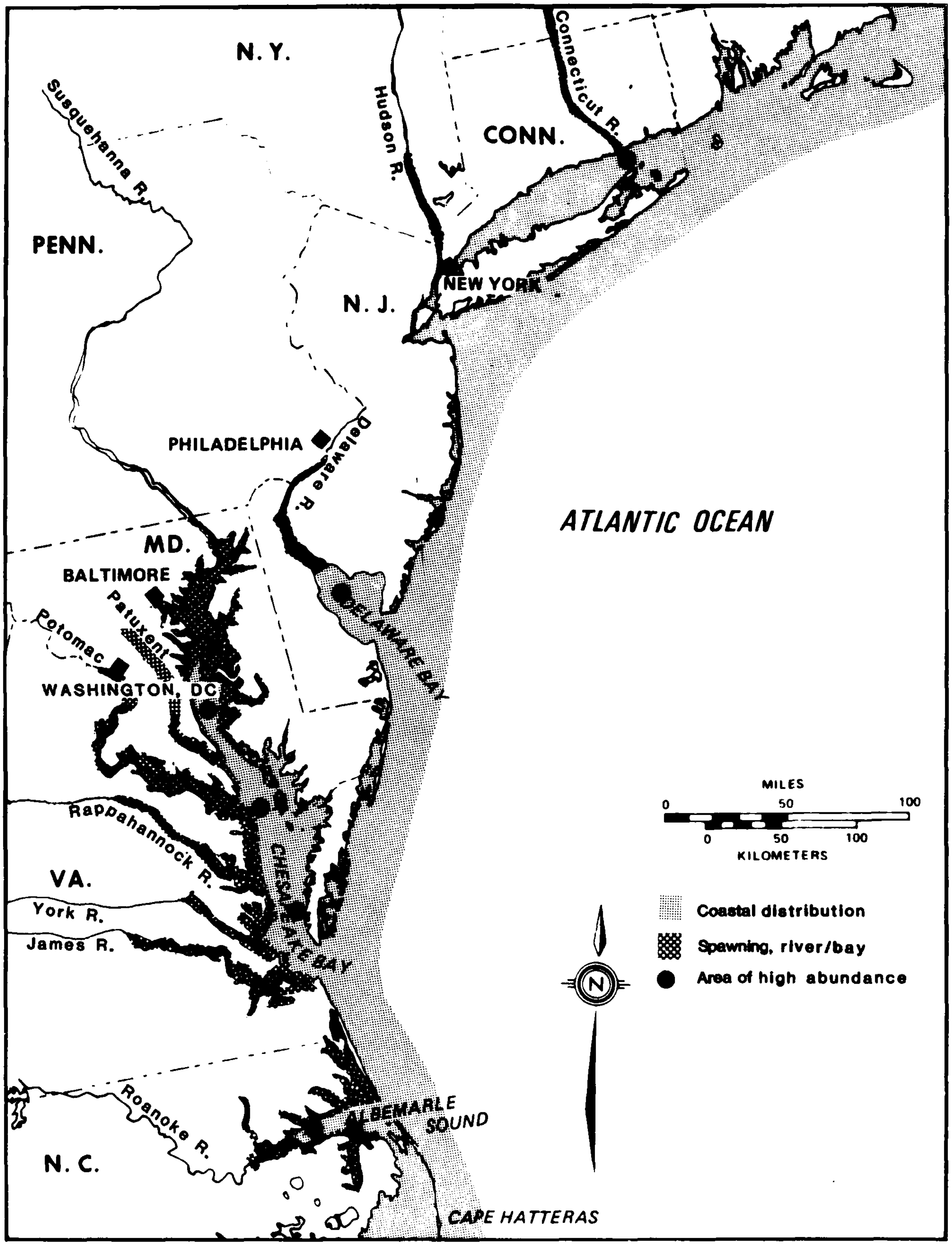


Figure 2. Mid-Atlantic distribution of the alewife and blueback herring.

standard length (SL); presented in Chambers et al. (1976).

Adults. Externally, by scale imbrication patterns and individual scale markings (Figure 3). Scale baseline and dividing line coincidental on alewife scales, not on blueback herring scales (O'Neill 1980; MacLellan et al. 1981). Internally, peritoneal lining uniformly dark in blueback herring; pale, grey, or silvery with dark punctations in alewife (Leim and Scott 1966; Scott and Crossman 1973). Shape of otolith distinctive (Scott and Crossman 1973) and differences described in Price (1978) and illustrated in O'Neill (1980). Biochemically distinguished by muscle myogen and retina LDH enzyme migration patterns (electrophoresis) (McKenzie 1973, 1975).

Alewives possess fewer vertebrae, dorsal rays, anal rays, and gill rakers on the first arch, in general, compared with blueback herring. Eye diameter to snout length ratios are also significantly different between the two clupeids, but mean values are close and ranges overlap (Messieh 1977). The applicability of these meristic characters for absolute species determination is limited since there is at least some overlap between species for each characteristic.

Though dorsal coloration has been cited as species-distinctive in fresh specimens (Bigelow and Schroeder 1953), this character may not be reliable. MacLellan et al. (1981) found no significant or detectable difference in dorsal coloration and observed that such coloration appeared to vary substantially with ambient lighting conditions.

## REASON FOR INCLUSION IN SERIES

The alewife and blueback herring are important ecologically and to a lesser extent as commercial fish species. Ecologically, these species are

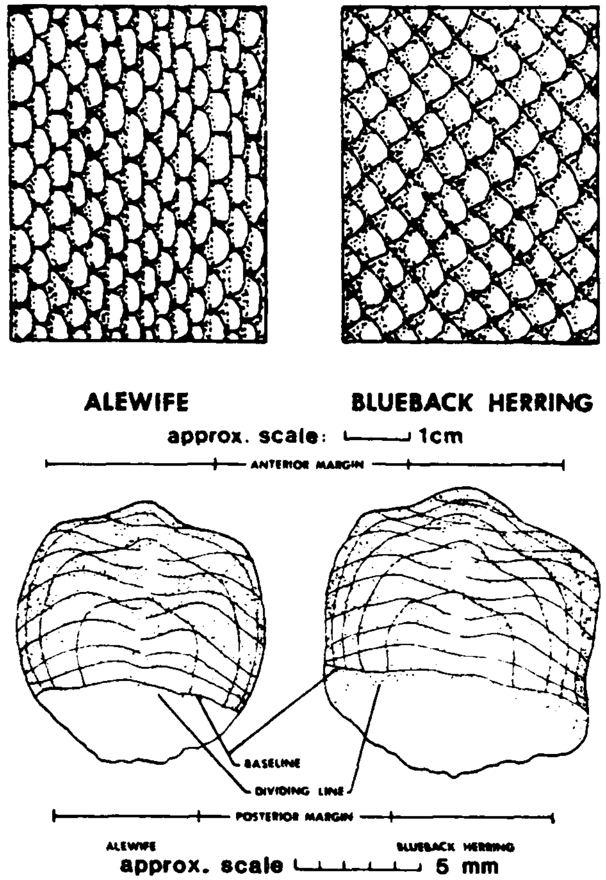


Figure 3. Scale imbrication patterns (top) and individual scale morphology (bottom) used for external discrimination of the alewife and blueback herring (from MacLellan et al. 1981; with permission of the Canadian Journal of Fisheries and Aquatic Sciences).

important links in estuarine and marine food webs, between zooplankton and top piscivores. Commercially, both species have recently (last two decades) gained in recognition and interest as sources of fish meal, fish oil, and fish protein, particularly for the animal food industries.

## LIFE HISTORY

### Reproductive Physiology/Strategy

Alewives and blueback herring are heterosexual, though hermaphroditism in landlocked populations of alewives from Lake Michigan has been reported (Edsall and Saxon 1968; Hlavek and Norden 1977). Females of both species are slightly larger and heavier than males of the same age (Cooper 1961; Netzel and Stanek 1966; Marcy 1969; Loesch and Lund 1977).

Some male anadromous alewives, and a slightly smaller percentage of females, spawn for the first time at age 3. Most fish of both sexes have spawned once by age 4, and all by age 5. Generally, males dominate age classes 3 to 5 on the spawning grounds, while females dominate age classes 7 and older. Blueback herring vary more than alewives in age of first spawning, though in general maturation rates are similar for the two clupeids (Joseph and Davis 1965; Loesch and Lund 1977; O'Neill 1980).

Age of first spawning, percentage of repeat spawners, and longevity in populations seem to decrease as one proceeds from north to south. Spawning populations of alewives in southern North Carolina comprised primarily 3-year-old fish, and no fish over 4 years old were found (Tyus 1974). In contrast, alewife spawning populations in Chesapeake Bay were represented by ages 3 to 8 (Joseph and Davis 1965), Connecticut River stocks by ages 3 to 8 (Marcy 1969; Loesch and Lund 1977), and Nova Scotian stocks (both alewives and blueback herring) by ages 4-10 (O'Neill 1980). Percentage of repeat spawners was 60% for alewives in Nova Scotia (O'Neill 1980), 61% in the York River, Virginia (Joseph and Davis 1965), and less than 10% in southern North Carolina (Tyus 1974). Blueback herring runs consisted of 65% and 75% repeat spawners in the York River and Nova Scotian waters, respectively (Joseph and Davis 1965; O'Neill 1980).

Fecundity of Connecticut River blueback herring ranged from 45,800 eggs (238-mm female) to 349,700 eggs (310-mm female) (Loesch and Lund 1977). From 10% to 30% of the initial number of eggs present in a female blueback herring remained after spawning. Left ovaries were significantly heavier than right ovaries, though left ovaries did not contain more eggs per gram of ovary than did right ovaries (Loesch and Lund 1977; Loesch 1981). Chesapeake Bay alewives ranged in fecundity from 60,000 to 100,000 eggs per female (Foerster and Goodbred 1978). The fecundity-to-age relationship for Georgia populations of blueback herring did not fit a linear relationship well ($r^2 = 0.42$) (Street 1969). It was suggested that the age-fecundity relationship is asymptotic for both alewives and blueback herring, and that "fecundal senility" may occur in all long-lived stocks of these species (Street 1969; Loesch and Lund 1977).

Spawning

Anadromous alewives and blueback herring spawn once a year, during spring or early summer, in fresh or brackish water (Raney and Massmann 1953). Males arrive at mouths of spawning rivers earlier than females (Cooper 1961; Tyus 1971; Richkus 1974a). Spawning environments vary from streams only a few meters (yards) wide and a few centimeters (inches) deep to large rivers such as the Delaware, Susquehanna, and Potomac (Mansueti 1956). Ponds, including barrier beach ponds, with an open outlet to the sea, are also used by alewives (Bigelow and Welsh 1925). Jones et al. (1978) cited Loesch (1968, 1969) as stating that blueback herring do not ascend into freshwater as far as alewives on spawning runs. However, Loesch (personal communication) said the statement pertained to the existing literature at that time, and findings reported in Loesch and Lund (1977) indicated that upstream distribution was a function of finding appropriate spawning habitats.

In laboratory tests, adult anadromous alewives from Rhode Island waters were capable of distinguishing water of their natal pond from water collected in nearby ponds (Thunberg 1971). Olfaction was shown to be the major sensory mechanism for homing behavior. Discriminate function analysis, however, by Messieh (1977) on St. Johns River, Florida, spawning stocks indicated considerable straying from home streams, particularly between adjacent spawning areas/stocks. Messieh (1977) hypothesized that the majority of stock mixing occurred during the prespawning period (late winter, early spring) rather than "impulsively" on the actual spawning runs. The majority of spawning alewives in Lake Mattamuskeet, North Carolina, used only one of four available canals for spawning migrations (Tyus 1974). It was hypothesized that since this canal was the only one available historically (built in 1907), the alewives may be exhibiting homing behavior. Tyus (1974) did not report, however, that this canal was also the shortest and most direct from bay to lake.

Spawning periods along the Atlantic coast range from late March through July, occurring later in the north. Within the mid-Atlantic region, nearly all alewife and blueback herring spawn from April through mid-July (Hildebrand 1963; Kissil 1969; Loesch 1969; Smith 1971; Tyus 1974; Loesch and Lund 1977). In general, alewives begin to spawn 3 to 4 weeks before blueback herring in sympatric areas. Spawning peaks are 2 to 3 weeks apart (Jones et al. 1978). Alewives began spawning at minimum water temperatures of 10.5°C (51°F) (Cianci 1969) and blueback herring at 14°C (57°F) (Loesch and Lund 1977). Both species cease spawning when water temperature exceeds 27°C (81°F) (Loesch 1969; Edsall 1970).

Blueback herring prefer spawning sites with fast currents and associated hard substrates (Loesch and Lund 1977). Brackish water or standing water habitats are rarely used. In contrast, alewives select a wide variety of spawning sites, using standing water and oxbows as well as mid-river sites (Kissil 1974). Several studies have described alewife spawning in ponds with an open connection to the ocean (e.g., Havey 1973; Kissil 1974), but no observations of pond spawning by blueback herring are documented. Apparently a considerable separation, both spatially and temporally, exists for spawning activity of anadromous alewives and blueback herring.

Loesch and Lund (1977) described spawning behavior of blueback herring. A spawning group composed of one female and several males swam in circles for several minutes, and males occasionally nudged the vent of the female. Swimming speed increased gradually until a deep dive occurred with subsequent release of eggs and milt simultaneously, very near the substrate. Spawning activities of both species occur diurnally and nocturnally, though the greatest activity apparently is nocturnal (Graham 1956; Edsall 1964). Both males and females migrate rapidly downstream after spawning, and total spawning time for a single migratory group is usually 5 days or less (Cooper 1961; Loesch and Lund 1977).

## Eggs

Until water-hardened, eggs of both species are demersal in still water and adhesive or pelagic in running water (Loesch and Lund 1977; Jones et al. 1978). After water-hardening (less than 24 hr), eggs lose their adhesive property and enter the water column. Fertilized, water-hardened eggs are green (alewife) to amber (blueback herring) and contain scattered, unequal (alewife) or numerous, small (blueback herring) oil droplets (Kuntz and Radcliffe 1917; Norden 1967). Egg diameter ranges from 0.80 to 1.27 mm for alewives and from 0.87 to 1.11 mm for blueback herring (Mansueti 1962; Norden 1967). Incubation time is approximately 80 to 94 hr at 20° to 21°C (68° to 70°F) and 55 to 58 hr at 22° to 24° C (72° to 75°F) for blueback herring eggs (Cianci 1969; Morgan and Prince 1976). Comparative values for alewives are approximately 360 hr at 7.2°C (45°F) (Edsall 1970), 178 hr at 12.7°C (55°F) (Kellogg 1982), 89 hr at 21.1°C (70°F) (Edsall 1970), 72 hr at 23.8°C (75°F) (Kellogg 1982), and 50 hr at 28.9°C (84°F) (Edsall 1970). An equation for predicting incubation time for alewife eggs from temperature (Edsall 1970) is:

$$T = 6.335 \times 10^{6} \times t$$

where T = time in days and t = incubation temperature in degrees F.

## Yolk-Sac Larvae

Yolk-sac larvae range from 2.5 to 5.0 mm total length (TL) at hatching, and average 5.1 mm TL at yolk-sac absorption (Mansueti 1962; Norden 1967). Duration of this stage is 2 to 5 days for alewife and 2 to 3 days for blueback herring (Mansueti 1962; Cianci 1969).

## Larvae

The larval stage lasts from yolk-sac absorption until transformation to the juvenile stage. Larval blueback herring range from 4.0 to 15.9 mm SL and larval alewives from 4.3 to 19.9 mm SL (Jones et al. 1978). Jones et al. (1978) provided detailed drawings of the developmental stages of eggs, yolk-sac larvae, and larvae of both alewives and blueback herring.

*Alosa* spp. larvae, primarily those of blueback herring and alewives, were present throughout upper Chesapeake Bay from hatching (approximately April 15) through June (Dovel 1971). Larvae exhibited slight downstream movement from presumed spawning areas in the bay, and were collected only in areas with salinities less than 12 ppt. *Alosa* spp. larvae in Nova Scotian rivers occurred in areas that were relatively shallow (<2 m, <6.6 ft), sandy, and warm, and were collected in or near areas of spawning adults (O'Neill 1980).

## Juveniles

Transformation to the juvenile stage is gradual, but is completed at approximately 20 mm TL. Scales first appear on juveniles between 25 and 29 mm TL, and are fully developed at 45 mm TL (Hildebrand 1963; Norden 1967).

Juvenile blueback herring in the James River, Virginia, exhibited a net upstream movement between June and October, presumably caused by contributions of juveniles from oxbows, side channels, and tributaries, which gradually moved down into the main river through the summer. Densities of juveniles were significantly higher near the surface than at 5-m (16.4-ft) depth throughout their residence in the river (Burbidge 1974).

Warinner et al. (1969) studied the distribution of juvenile alewives and blueback herring in the Potomac River over the first 6 months of life (Figure 4). Four important conclusions were evident.

1) Both species exhibited apparent upstream movement, averaging 24 km (15 mi) over 4 months, until the inception of emigration in October.

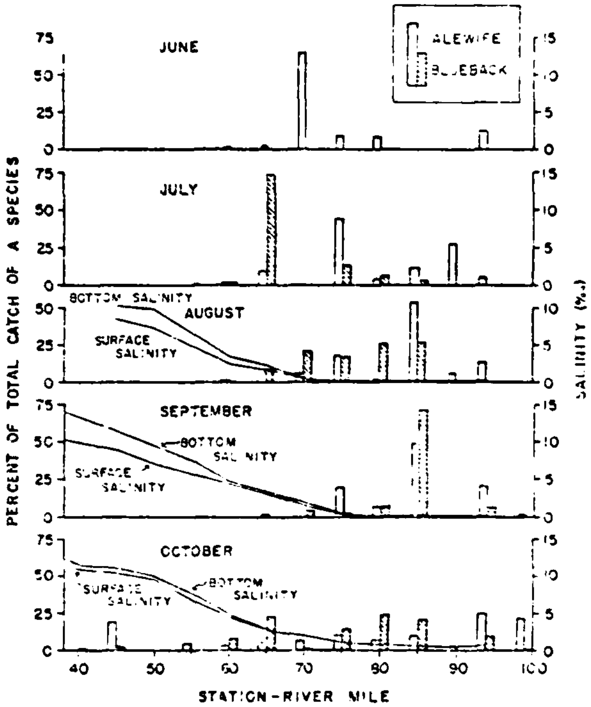

Figure 4. Seasonal distribution of juvenile river herring by river mile in the Potomac River, Maryland. No data are shown for November because fish were absent in the study area (from Warinner et al. 1969).

2) Both species were virtually absent in the study area by November.

3) Juvenile blueback herring outnumbered alewives 19:1 overall.

4) Juvenile alewives were most abundant in surface waters through September, and increased in abundance at 4.6 m (15 ft) and on the bottom in September and October, prior to emigration. In contrast, juvenile blueback herring maintained high abundance in surface waters through October, increased in abundance at 4.6 m in November, and were never collected in bottom trawls throughout the study period.

Significant diel movements of juvenile alewives and blueback herring in Virginia rivers were found (Loesch et al. 1982a). Fish moved toward the bottom during the day and toward the surface at night. Blueback herring were more sensitive to the sky-opacity index and exhibited more extensive vertical movement patterns in relation to changing light intensity than alewives. This movement pattern was also noted for juvenile alosids in the Potomac River (Warinner et al. 1969).

In most Atlantic coast populations, juvenile alewives and blueback herring emigrate from freshwater/estuarine nursery areas between June and November of their first year of life (Burbidge 1974; Kissil 1974; Richkus 1975; O'Neill 1980). Juvenile river herring in upper Chesapeake Bay did not emigrate until early spring of their second year, and such migrations were comparatively rapid once they began (Dovel 1971). This was the only report of nonmigratory first-year juveniles, except for the dwarf, nonmigratory population of alewives described by Foerster and Goodbred (1978) from the Susquehanna River.

Stimulatory variables influencing the initiation of migratory "waves" (Richkus 1975) of juvenile alewives from nursery habitats include heavy rainfall (Cooper 1961), high water (Kissil 1974; Richkus 1975), and sharp declines in water temperature (Richkus 1975). Richkus (1975) observed that (1) such waves lasted 2 to 3 days, regardless of length of time of environmental change; (2) migrations peaked in late afternoon; and (3) the magnitude of a migratory wave was not related to the magnitude of environmental change. Most (60% to 80%) juveniles emigrated on only a small percentage (7% to 8%) of the available days (Richkus 1975).

Significant numbers of juvenile alewives and blueback herring were captured during winter in the Mullica River Estuary, New Jersey, indicating the importance of this area for overwintering (Milstein 1981). Blueback herring was third in percent representation and alewives seventh among 53 species collected. Both species were captured out to 8 km (5 mi) offshore, which is near the outer limit of salinity/temperature influences from the Mullica River Estuary. Overwintering fish chose temperatures between 4.5°and 6.5°C (40° and 43.7° F) and salinities from 29 to 32 ppt. Densities of overwintering juveniles increased steadily from December to March, then declined in April. The alewife-to-blueback herring ratio in all samples combined was 1:5 (Milstein 1981).

## Adults

Little information is available concerning the life history or biology of alewife and blueback herring stocks once the juveniles emigrate to the sea at age 0+ or 1+. A literature search indicated that much research needs to be conducted in stock identification, offshore exploitation rates, foreign fishing operations, and general life history, movement, migration patterns, feeding behavior, and ecology of these clupeids in offshore waters.

Neves (1981) summarized 16 years of catch data from National Marine Fisheries Service trawl surveys conducted along the Atlantic coast, between Cape Hatteras and Nova Scotia. Samples were taken out to depths of 200 m (656 ft). The majority of the catch of alewives and blueback herring was taken at sampling stations where water depth was less than 100 m (328 ft). Alewives and blueback herring collected ranged from 60 to 350 mm fork length (FL), and alewives outnumbered blueback herring approximately 10:1 for all samples combined. Statistical analysis determined that alewives were most abundant at depths between 56 and 110 m (184 and 361 ft), while blueback herring were most abundant between 27 and 55 m (89 and 180 ft). In summer and fall, catches of both species were confined to the sampling area north of 40° north latitude, in three general areas: Nantucket Shoals, Georges Bank, and the perimeter of the Gulf of Maine. Winter catches were between 40° and 43° north latitude. Spring catches were distributed over the entire Continental Shelf in the study region (Neves 1981).

Adult alewives and blueback herring chose only a small portion of Georges Bank, specifically the western slope at 41°, 29′ north latitude and 68°, 34′ west longitude, as an area of residence in July and October, 1964 (only months sampled) (Netzel and Stanek 1966). Alewives outnumbered blueback herring in these samples. All mature age classes were represented, but age 0+, 1+, and 2+ fish were not captured.

Alewives and blueback herring, like other clupeids, may exhibit seasonal movements in conjunction with preferred isotherms (or preferred isotherms of forage organisms) (Collins 1952; Leggett and Whitney 1972); however, direct evidence is lacking (Richkus 1974b). Feeding and vertical migration are probably controlled by light intensity patterns within thermal preference zones (Richkus and Winn 1979; Neves 1981).

# GROWTH CHARACTERISTICS

## Growth Rates

Growth rates (L in mm, wt in g) of young-of-the-year blueback herring in the James River, Virginia, are given below. Blueback herring achieved a mean fork length of 35.6 mm and weight of 3.68 g by 15

November of their first year (Burbidge 1974). Growth rates of young-of-the-year blueback herring in the Cape Fear River, North Carolina, were similar to those for the James River population (Davis and Cheek 1966).

| Period | Change in L per day (mm) | Change in wt per day (g) |
|---|---|---|
| Mid-June to mid-July | 0.29 | 0.03 |
| Mid-July to mid-Aug. | 0.12 | 0.01 |
| Mid-Aug. to mid-Sept. | 0.15 | 0.01 |
| Mid-Sept. to mid-Oct. | 0.29 | 0.05 |
| Mid-Oct. to mid-Nov. | 0.32 | 0.05 |

Young-of-the-year alewives apparently grow faster than blueback herring. In the Northeast Cape Fear River, North Carolina, young alewives reached a mean fork length of 44.0 mm and 47.8 mm in August of 1964 and 1965, respectively (Davis and Cheek 1966). Certainly some of the apparently faster growth of young alewives is due to an earlier spawning period and therefore a longer growing season. Growth of young alewives between hatching and fall emigration from nursery areas averaged 102 mm TL in lower Chesapeake Bay (Joseph and Davis 1965), and 113 mm TL in the Connecticut River (Marcy 1969). Average length of juvenile emigrants, sampled daily over three seasons (1970-72) in Hamilton Reservoir, Rhode Island, ranged from 25 mm SL to 88 mm SL (30 mm TL to 105 mm TL) (Richkus 1975).

Little information is available on growth rates of these clupeids between age 0+ and the time of first spawning. Age 1 alewives reached 147 mm TL by the end of their second summer in the Connecticut River Estuary; however, only males of that age were collected (Marcy 1969). Age 2 alewives and blueback herring in Albemarle Sound, North Carolina, reached 153 mm FL and 148 mm FL, respectively, by the end of their third summer (Kornegay 1978). On Georges Bank, age 2 fish of both species reached approximately 180 mm TL by the end of their third summer (Netzel and Stanek 1966).

Lengths at age for sexually mature alewives and blueback herring are given in Table 1. In general, alewives are longer than blueback herring of the same age. Within each species males are smaller than females of the same age, and growth rates for both species level off after reaching sexual maturity (compared to growth rates of immature fish). Mean weights of spawning alewives in Damariscotta Lake, Maine, ranged from 153 g (5.4 oz) (males) and 164 g (5.8 oz) (females) at age 3, to 325 g (11.5 oz) (males) and 356 g (12.6 oz) (females) at age 7. One 8-year-old female weighed 455 g (16.0 oz) (Walton 1979).

Otolith and scale-aging techniques for alewives and blueback herring from Albemarle Sound, North Carolina, agreed nearly 100% for age classes 0, 1, and 2, but consistency between methods decreased progressively as fish age exceeded 3 years (Kornegay 1978). The scale-aging technique tended to underestimate the proportion of age 4 and 5 individuals and overestimate the proportion of age 6 and 7 individuals for both species. Growth rates backcalculated from scales tended to be higher than those backcalculated from otoliths. Regressions for prediction of fork length from scale and otolith measurements are available in Kornegay (1978).

Messieh (1977) gave von Bertalanffy growth equations for alewives and blueback herring in the St. John River, New Brunswick, as follows:

Table 1. Length (mm FL) at age (yr) for selected Atlantic coast spawning populations of alewives and blueback herring.

| Location[a] | Species/sex[b] | Length (mm FL) at age (yr) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AS | A/M | 236 | 249 | 256 | 259 | 268 | 279 | - |
| AS | A/F | 254 | 261 | 270 | 277 | 283 | 287 | - |
| AS | B/M | 231 | 241 | 245 | 251 | 258 | 270 | - |
| AS | B/F | 245 | 252 | 258 | 264 | 268 | 280 | 307 |
| CB | A/M | 229 | 239 | 249 | 254 | 259 | - | - |
| CB | A/F | 239 | 249 | 259 | 264 | 274 | 282 | - |
| CR | A/M | - | 265 | 278 | 290 | 301 | - | - |
| CR | A/F | - | 284 | 284 | 299 | 308 | 324 | - |
| CR | B/M | 258 | 266 | 280 | 286 | 298 | - | - |
| CR | B/F | 261 | 277 | 291 | 301 | 311 | - | - |
| GB[c] | A/MF | 270 | 284 | 294 | 306 | 316 | 327 | 330 |
| GB[c] | B/MF | 240 | 269 | 281 | 292 | 302 | 313 | - |
| DL | A/M | 260 | 278 | 301 | 315 | 318 | - | - |
| DL | A/F | 273 | 283 | 309 | 324 | 333 | 356 | - |

[a]AS = Albemarle Sound, North Carolina (Pate 1974); CB = Chesapeake Bay (Joseph and Davis 1965); CR = Connecticut River (Marcy 1969); GB = Georges Bank (Netzel and Stanek 1966); DL = Damariscotta Lake, Maine (Walton 1979).

[b]A/M = alewife males; A/F = alewife females; A/MF = alewife males and females; B/M = blueback herring males; B/F = blueback herring females.

[c]Values in mm TL.

$$MA\ L = 291.67(1 - e^{-0.441(t - 0.142)})$$

$$FA\ L = 310.48(1 - e^{-0.400(t - 0.103)})$$

$$MB\ L = 231.33(1 - e^{-0.590(t - 0.338)})$$

$$FB\ L = 259.85(1 - e^{-0.469(t - 0.283)})$$

where MA is for male alewives, FA is for female alewives, MB is for male blueback herring, FB is for female blueback herring, L = fork length (mm) at time t in years, and e is the base of natural logarithms.

Also given were von Bertalanffy growth equation parameters and modified Walford plots for four separate areas in the St. John River drainage, where different spawning stocks were suspected. The equations given above are for all study areas combined, since differences in growth parameters among areas were small (Messieh 1977).

### Length-Weight Relationships

Length-weight relationships for alewives and blueback herring of the St. John River, New Brunswick, were given in Messieh (1977) as follows:

| | |
|---|---|
| Male alewives | logW=3.235logL-5.420 |
| Female alewives | logW=3.192logL-5.294 |
| Male blueback | logW=2.904logL-4.702 |
| Female blueback | logW=2.472logL-3.693 |

L=Fork length in mm, W=Weight in g

Condition factors (K) for young-of-the-year blueback herring of the James River, Virginia, averaged 1.60, 1.68, 1.57, 1.37, 1.22, and 1.18 for the months of June, July, August, September, October, and November, respectively (Burbidge 1974). It was hypothesized that a massive flood in the study area between August and September may have reduced zooplankton availability which, in addition to normal seasonal declines in zooplankton populations, resulted in the observed deterioration in the condition factor (Burbidge 1974).

## THE FISHERY

### Commercial Fisheries

U. S. commercial landings of river herring (both species combined) along the Atlantic coast were 4,948 mt in 1980 and 3,754 mt in 1981. These landings were worth $779,000 and $671,000, respectively. The current 5-year running average of river herring landings (1977-81) by U. S. fisheries was 5,003 mt/yr. More than 90% of the U. S. commercial catch occurred within 4.8 km (3 mi) of the coast (National Marine Fisheries Service, NMFS, 1982). They are commercially fished during spawning runs. Pound nets are the most commonly used gear (Joseph and Davis 1965; Pate 1974). The majority of U. S. landings was used for fish meal and fish oil to be added to fertilizer, pet food, and domestic animal feed. A minor portion was used for fishing bait, and the remainder was sold salted or fresh for human consumption. Roe from these species is canned and is highly valued (Joseph and Davis 1965; Street and Davis 1976; Merriner 1978).

The total foreign catch of river herring within the U. S. Fishery Conservation Zone (FCZ) was 24.6 mt in 1980 and 13.9 mt in 1981. Cuba took greater than 90% of the 1980 foreign landings, and Poland captured approximately 75% of the 1981 foreign catch. All of the 1980 and 1981 foreign landings were taken from the North Atlantic region (north of Cape Hatteras) (NMFS 1982).

In domestic commercial fisheries in Albemarle Sound, North Carolina, surveyed in 1972, age 4 and 5 fish represented 60% or more of the inshore catch of alewives and blueback herring (Pate 1974). Significant contributions also occurred from age 3, 6, and 7 fish (at least 30% of total catch). Ratio of alewives to blueback herring in the 1972 catch was 2:3, and sex ratios within species were near 1:1. First-time spawners accounted for 50% and 57%, respectively, of the landings of blueback herring and alewives. Historically, the Chowan River has been the most important inshore fishing grounds in Albemarle Sound. Peak landings usually occur in late April, coinciding with the spawning runs of the more common blueback herring in North Carolina (Pate 1974). In the Potomac River, Maryland, the 1974 commercial catch was dominated by alewives in March and early April, while blueback herring landings peaked in late April and May. The total ratio of alewives to blueback herring in the 1974 catch was 1:4 (Merriner 1978).

Total landings and catch per unit effort in North Carolina and Virginia waters have declined substantially over the last decade since peaking in 1969 at 35,302 mt (Street and Davis 1976; Merriner 1978). The decline was due to offshore trawl fisheries, which did not begin operating until 1967 (McCoy 1975). These fisheries were not and are not size selective, and 65% of the 1975 offshore trawl landings of river herring consisted of immature fish (Street and Davis 1976). In contrast, all inshore commercial catches historically were captured from sexually mature populations, where escapement rates can be controlled to prevent overexploitation (McCoy 1975).

The State of Maine has developed an Alewife Management Plan for anadromous stocks within their State jurisdiction (Walton et al. 1976). Historical landings and management are reviewed and management recommendations presented for the alewife runs of each coastal county. Aspects of life history, biology, and management of Virginia and North Carolina stocks of anadromous alewives and blueback herring were reviewed by Rulifson and Huish (1982). In addition, recommendations for development of a management plan are presented and discussed.

## Recreational Fisheries

Recreational fishing for alewives and blueback herring is significant during spring spawning runs in areas such as Delaware Bay, Chesapeake Bay, and Albemarle Sound (Pate 1974). The disposition of the catch, however, is not well documented. Apparently, most of the recreational catch serves as bait for other sportfish (NMFS 1980). The numbers and weights of the recreational catch for each species are unknown, because published surveys lump these two species with menhadens, shads, other herrings, and sardines. The NMFS estimated that 6,169,000 total "herrings" were captured by Atlantic coast recreational fishermen in 1979.

## Population Dynamics

Sex ratios/age structure. On spawning runs, total sex ratios of adults are nearly 1:1 in most areas. Percentage of male alewives in the spawning populations of Bride Lake, Connecticut, was 55.6% (Kissil 1974), compared to 53.8% and 53.0% for alewives and blueback herring in the Connecticut and Thames Rivers (Marcy 1969), and 58.0% in a later study on Thames River blueback herring (Loesch and Lund 1977). It has been suggested that the slight dominance of males in spawning populations is due to their earlier sexual maturity compared to that of females (Kissil 1974). Sex ratios (% males) by age for 1966 and 1967 spawning populations of alewives from the Connecticut and Thames Rivers, Connecticut, (data combined) were 72.3%, 63.7%, 49.7%, 33.8%, and 0.0% for fish of age 4, 5, 6, 7, and 8, respectively. Ratios for blueback herring were 80.0%, 79.4%, 64.5%, 36.9%, and 22.6% for fish of age 3, 4, 5, 6, and 7, respectively (Marcy 1969).

Life stage abundance/reproductive and mortality rates. In Bride Lake, Connecticut, an estimated 184,151 adult alewives spawned $2.05 \times 10^{10}$ eggs in 1966. Subsequently, 257,000 juveniles were counted as they emigrated during the summer and fall. This generated a total freshwater mortality rate from egg stage to emigration of 99.9987%, and indicated that 2.88 juveniles left the lake for each adult female that spawned. Combined with repeat spawning proportions, this level of juvenile production seemed adequate for sustaining the spawning population in Bride Lake (Kissil 1974). Total freshwater mortality rate of spawning adults in Bride Lake was reported at 57.4% and 48.6%, in 1966 and 1967, respectively.

Havey (1973) investigated juvenile production and adult mortality of the alewife population in Love Lake, Maine. The number of emigrants ranged from 220 to 439,062 fish over an 11-year study period. Juvenile emigrants produced per female per year varied from 12 to 3,209, and biomass production of emigrants ranged from 0.09 to 21.50 kg (0.2 to 47.4 lb) per female per year. Significant linear relationships between juvenile emigrant abundance and spawning population size 4 years later, and between the log of female escapement and the log of juvenile emigrant abundance were found. Total adult freshwater mortality averaged 90.7% and ranged from 66% to 100% over the 11-year-study period (Havey 1973). Total annual mortality rates for anadromous alewives in Long Pond, Maine, were 78.6% between age 5 and 6, and 74.4% between age 6 and 7 (Havey 1961). Freshwater postspawning mortality for all age groups averaged 41% and ranged from 32% to 67% over the 6-year study period (Havey 1961). Results from these two studies in Maine and the study by Kissil (1974) in Connecticut indicated that juvenile production and adult freshwater mortality may vary considerably among spawning areas and among different years in the same spawning area.

Methods of determining true spawning population size of alewives, by subsampling at various times on fishways on the Parker River, Massachusetts, were investigated by Rideout et al. (1979). Visual counts during one 10-min period each hour produced estimates (by computer program) with less than 5% error. Visual counts during one 5-min period each hour or one 10-min period each 1.5 hours were significantly higher in magnitude of potential error (Rideout et al. 1979).

Stock identification. Although Thunberg (1971) found that alewives were capable of homing behavior through olfaction, Messieh (1977) concluded that considerable mixing between presumed spawning stocks occurred on the spawning runs. Though a majority of the alewives exhibited homing, a substantial number (by meristic comparisons) from each presumed stock did not home (Messieh 1977).

Evidence for a nonlandlocked, nonmigratory, self-sustaining dwarf population of alewives residing in the mouth of the Susquehanna River was presented by Foerster and Goodbred (1978).

## ECOLOGICAL ROLE

### Food Habits

Alewives and blueback herring are primarily zooplanktivores, though fish eggs, crustacean eggs, insects and insect eggs, and small fishes may be important foods in some areas or for larger individuals (Bigelow and Schroeder 1953). Larvae begin feeding on zooplankton immediately upon formation of a functional mouth (about 6 mm TL), concentrating on the relatively small cladocerans and copepods, and adding larger species of these groups to the diet as their mouths can accommodate them (Norden 1968; Nigro and Ney 1982).

Stomachs from young-of-the-year blueback herring collected in the James River, Virginia, contained primarily (by volume) Bosmina spp., copepod nauplii, copepodites, and the adult copepods Eurytemora affinis and Cyclops vernalis. Diaphanosoma brachyurum and Canthocamptus robertcokeri were also minor food items, but were not utilized during all seasons (Burbidge 1974). Electivity (Ivlev 1961) was strongest for adult copepods; neutral for Bosmina spp., copepodites, and D. brachyurum; and strongly negative for copepod nauplii. Daily ration for young-of-the-year ranged from 438 g-cal per fish per day in July and August to 215 g-cal per fish per day in October and November (Burbidge 1974).

Young-of-the-year alewives in Hamilton Reservoir, Rhode Island, consumed primarily chironomid midges during July, switching to cladocerans in August and September (Vigerstad and Cobb 1978). Davis and Cheek (1966) compared the food habits of young-of-the-year alewives and blueback herring in the Cape Fear River, North Carolina. Blueback herring selected copepods and dipteran larvae more frequently (by percent of stomachs containing items) than did alewives, while alewives consumed more ostracods, insect eggs, and insect parts than did blueback herring. Crustacean eggs in the diets were similarly common (>80% of stomachs) for both clupeids. Overlap of either diet with that of young-of-the-year American shad Alosa sapidissima was not extensive because of the broader range of foods chosen by shad (Davis and Cheek 1966).

Few direct studies have been devoted to food habits of anadromous adult alewives and blueback herring. In general, they are zooplanktivores, with the size range and diversity of available prey increasing as the fish grow and can accommodate larger items. Considerable piscivority may develop in landlocked populations (Kohler and Ney 1981).

## Feeding Behavior

Alewives and blueback herring feed in schools of varying size, most extensively during daylight. At night, schools disperse, and feeding activity is negligible or casual, and probably by filter feeding (Burbidge 1974; Janssen 1978). Peak stomach fullness occurred at 6 PM and peak stomach emptiness occurred at 7 AM in blueback herring from the James River, Virginia (Burbidge 1974). In addition, young-of-the-year blueback herring fed more actively near the surface than at 5 m (16 ft) depth, even though high densities were present at both depths (Burbidge 1974).

In laboratory tests (Janssen 1976), alewives exhibited three feeding modes: (1) particulate feeding on individual prey, (2) filter feeding with mouth agape and rapid swimming bursts, and (3) gulping several prey at once but not swimming at the rapid speed used in the filter-feeding mode. Size selectivity of prey items was highest in mode (1), moderate in mode (3), and negligible in mode (2). Adult Lake Michigan alewives and a major food organism, Mysis relicta, exhibited coincidental, crepuscular vertical migrations, from daytime residence near the bottom to just below the thermocline at night (Janssen and Brandt 1980). Such a diel vertical migration, though probably not in relation to a thermocline, may occur in anadromous populations residing in estuaries or marine coastal habitats.

## Competitors

Little study has been devoted to competitive interactions of anadromous alewives or blueback herring. Because of general similarities in diet and feeding behavior, some competition for food likely occurs between the two species. Loesch et al. (1982a) described a spatial separation between young alewives and blueback herring in the same habitat, which may lead to reduced competition for food, at least among juveniles.

## Predators

Alewives and blueback herring are highly utilized forage species for many riverine, estuarine, and marine piscivores, including airborne predators such as gulls and terns (Commonwealth of Massachusetts 1976). Bluefish (Pomatomus saltatrix), weakfish (Cynoscion regalis), and striped bass (Morone saxatilis) are predators of these clupeids. Pelagic, schooling predators such as these are more likely to use schooling clupeids for forage compared to a solitary predator (Cooper 1961; Tyus 1974).

# ENVIRONMENTAL REQUIREMENTS

Some research has been conducted to delineate the specific environmental requirements of anadromous alewife and blueback herring. Much of the available information was derived from tests on landlocked populations (particularly Lake Michigan alewives). Applicability of environmental requirement data for landlocked populations to anadromous populations is unknown. Since data from landlocked populations are major sources of information on environmental requirements, they are presented but should be interpreted with caution.

## Temperature

The effects of incubation temperature on alewife eggs from Lake Michigan were studied by Edsall (1970). At least some eggs hatched at test temperatures between 7° and 29.5°C (44.6° and 85.1°F). Optimum incubation temperature for hatching was 18° C (64°F); 38% hatch was observed. Egg mortality over the first 36 hr ranged from 22% at temperatures between 3.5° and 6.0°C (38° and 43° F) to 66% at temperatures between 25.5° and 28.5°C (78° and 83°F). Egg mortality rate was directly correlated to incubation temperature (Edsall 1970). An upper lethal temperature of 29.7°C (85°F) was reported for alewife eggs from the Hudson River, New York (Kellogg 1982). Maximum percentage hatch occurred at 20.8°C (69°F), and at least some eggs hatched at test temperatures between 12.7° and 26.7°C (55° and 80°F).

Blueback herring eggs collected from the Washademoak River, New Brunswick, Canada, were subjected to time-temperature regimes experienced in a powerplant cooling system (Koo and Johnston 1978). Compared to larval deformity rate, egg mortality and hatchability were not good indicators of the effects of temperature change. Deformity rate of larvae, acclimated at 19°C (66°F) and exposed to a 10°C (18°F) increase in temperature for 5 to 180 min, varied from 0 to 25% (control 0-5%). Deformity rate increased to 100% under the same conditions except with a 15°C (27°F) temperature elevation. Deformities ranged from minor curvature of the spine to complete lack of normal larval form or behavior. Deformities were permanent and would not have allowed such larvae to survive in natural environments (Koo and Johnston 1978).

Edsall (1970) reported two aspects of temperature effects on larval alewives from Lake Michigan. Survival time of unfed larvae was 3.8 days at 10.5°C (51°F), 7.6 days at 14.5° to 15°C (58° to 59°F), and 2.4 days at 26.5° to 28°C (80° to 82°F). A functional jaw did not develop in fish from eggs/larvae held at or below 10°C (50°F), even though some eggs hatched at such temperatures. Kellogg (1982) reported an upper temperature tolerance of 31°C (88°F) for alewife larvae from the Hudson River, New York, acclimated to 14°C (57°F). Average daily gain in larval weight was directly proportional to water temperature; higher growth occurred at higher temperatures. A maximum larval growth rate of 0.084 g/day occurred at 29.1°C (84°F), while maximum net gain in biomass (a function of both survival and growth) occurred at 26.4°C (79.5°F) (Kellogg 1982).

Young-of-the-year alewives (19 to 31 mm TL) from the Hudson River, New York, preferred a water temperature of 26.3°C (79°F) when given a choice in a controlled thermal gradient (Kellogg 1982). Young-of-the-year alewives from Lake Michigan exhibited critical thermal maxima (CTM is the mean of temperatures at which experimental fish lose equilibrium) of 28.3°C (83°F), 32.7°C (91°F), and 34.4°C (94°F) at acclimation temperatures of 11°C (52°F), 19°C (66°F), and 25°C (77°F), respectively (Otto et al. 1976). The equation for predicting CTM from acclimation temperature was:

$$CTM = 21.9 + 0.5(TA) \qquad r^2 = 0.96$$

where TA = acclimation temperature in degrees Celsius.

Otto et al. (1976) also reported that CTM values were 3° to 6°C (5.4° to 10.8°F) higher for young-of-the-year alewives than for adults when tested at the same acclimation temperatures.

In laboratory tests, preferred (selected) temperatures of juvenile alewives and blueback herring (ages 0+ and 1+) collected from the Delaware River, New Jersey, ranged from 20° to 22°C (68° to 71°F) at salinities of 4 to 6 ppt and acclimation temperatures from 15° to 21°C (59° to 70°F) (Meldrim and Gift 1971). Davis and Cheek (1966) captured juvenile blueback herring in the Cape Fear River seasonally in areas where water temperatures ranged from 11.5° to 32°C (53° to 89°F). Juvenile alewives in the same watershed were captured at temperatures between 13.5° and 29°C (56° and 84°F).

School formation patterns and daily rhythms of adult Lake Michigan alewives were affected by changes in temperature in laboratory tanks (Colby 1971). As water temperature dropped below 6.7°C (44°F), normal feeding behavior was disrupted and cruising speed of schooling fish decreased. Below 4.5°C (40°F), normal schooling behavior was significantly affected. At temperatures between 2.0° and 2.8°C (35.5° and 37° F), alewives lost orientation, swam into the sides of the test chamber, and ceased feeding and schooling.

In cold shock tests with adult alewives from Lake Michigan, transfers to test temperatures less than 3°C (37.4° F) caused 100% mortality regardless of original acclimation temperatures (Otto et al. 1976). Magnitude of temperature-decrease tolerated increased gradually with increasing acclimation temperature. At least some alewives survived a temperature decrease of 10°C (18°F), independently of acclimation temperature, as long as the total test temperature did not drop below 3°C (37.4°F) (Otto et al. 1976).

Stanley and Colby (1971) investigated electrolyte balance and osmoregulation of Lake Michigan alewives in relation to temperature change. Transfers of fish acclimated at warm temperatures to cold temperatures caused levels of $Na^+$, $K^+$, and $Ca^{++}$ in blood and muscle to move towards an equilibrium with salinity of the acclimation environment (increased body concentrations in salt water, decreased body concentrations in freshwater). Apparently, the test fish temporarily lost the ability to osmoregulate upon exposure to cold, independently of the salinity of the test environment.

## Salinity

Though little direct information exists, anadromous alewives and blueback are apparently highly tolerant of salinity changes (Cooper 1961; Chittenden 1972). No mortality of adult blueback herring from either gradual or abrupt changes in salinity, including direct transfers from fresh to salt water and the reciprocal, was observed by Chittenden (1972). Blood and muscle concentrations of the electrolytes $Na^{+}$, $K^{+}$, and $Ca^{++}$ were similar in fish held in sea water and freshwater of the same temperature, indicating that after a period of acclimation, alewives were efficient osmoregulators in either environment (Stanley and Colby 1971).

## Other Environmental Factors

Location of appropriate spawning sites and substrates is important not only to the perpetuation of each species but also for natural "reproductive segregation" between two otherwise very similar species. Blueback herring prefer spawning sites with strong currents and associated hard substrates (Loesch and Lund 1977). They are relatively specialized compared to alewives, which use a wide variety of spawning sites, from standing river water, oxbows, coastal ponds, and tiny streams to fast-water, mid-river sites. Therefore, changes in water currents or substrates in spawning rivers used by blueback herring may affect that species more than the alewife, because of the more specific spawning site requirements of blueback herring.

Young-of-the-year alewives and blueback herring from the Cape Fear River system, North Carolina, selected areas where free carbon dioxide ranged from 4 to 22 ppm, alkalinity from 5 to 32 ppm, dissolved oxygen from 2.4 to 10.0 ppm, and pH from 5.2 to 6.8 (Davis and Cheek 1966).

In an experiment designed to test the effects of suspended sediments on hatching of alewife eggs (Schubel and Wang 1973), a naturally occurring fungus in the sediment infected all test eggs prior to hatching, and terminated the experiment. Although the extent of infection may have been enhanced by laboratory conditions, the attempt indicated that high levels of suspended sediment during or after spawning may significantly increase infection rates of eggs from naturally occurring fungi in sediments (Schubel and Wang 1973). Auld and Schubel (1978), however, found that suspended sediments in concentrations of 100 ppm or less had no significant effect on hatchability of alewife or blueback herring eggs.

The influence of certain environmental variables associated with passage of migratory adult alewives through (around) hydrological obstacles has been investigated. Blood lactic acid concentrations, measured in alewives moving through a pool-and-weir fishway, were representative of moderate activity and energy expenditure (Dominy 1971, 1973). Mean levels of blood lactic acid in alewives passing through the fishway were less than half the levels found for heavily exercised fish in the laboratory. Rest pools along the course of the fishway allowed blood lactic acid levels to drop to levels comparable with those for alewives in a rested state in the laboratory.

Upstream migratory patterns of adult alewives through a Rhode Island river fishway were harmonic with diurnal periodicity. Periodicity was correlated with magnitude of incident solar radiation (Saila et al. 1972). Richkus (1974a) corroborated this light-dependent migratory activity; he also observed that within activity patterns determined by light intensity, changes in water temperature strongly influenced specific timing of alewife upstream movement. Juvenile downstream emigration from Hamilton Reservoir, Rhode Island, during summer and fall was inhibited by the bright sunlight-bridge shade interface present at a road bridge on the lower end of the reservoir. Higher emigration rates under this bridge were observed on cloudy days (Richkus 1974a).

Environmental Contaminants

The $LC_{50}$ of total residual chlorine for blueback herring eggs ranged from 0.20 to 0.32 ppm. Larvae from eggs exposed to sublethal concentrations of total residual chlorine were all deformed (Morgan and Prince 1977). Concentrations of kepone greater than 0.3 ppm (termed the "action level" for possible closure of a fishery) were found in body tissues of young-of-the-year alewives and blueback herring collected from the James and Chickahominy Rivers, Virginia (Johnson et al. 1978; Loesch et al. 1982b). Kepone was also present in young alewives and blueback herring from the Mattaponi and Pamunkey Rivers, Virginia (in concentrations less than 0.3 ppm), but was not present in detectable quantities in fish from the Rappahannock River, Virginia, and the Potomac River, Maryland (Loesch et al. 1982b).

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**REPORT DOCUMENTATION PAGE**

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| | 6. |
| 7. Author(s): Clemon W. Fay, Richard J. Neves, and Garland B. Pardue | 8. Performing Organization Rept. No. |
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15. Supplementary Notes

* U.S. Army Corps of Engineers report No. TR EL-82-4.

16. Abstract (Limit: 200 words) Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in impact assessment. The alewife and blueback herring, Alosa pseudoharengus and Alosa aestivalis, are important species in estuarine and marine ecosystems as links between the zooplankton they consume and top piscivores. Both anadromous and landlocked populations exist. Some individuals mature by age 3, and all mature by age 5. Repeat spawning is common. Spawning environments range from streams only a few centimeters deep to large rivers. Alewives will also spawn in ponds with an open connection to the sea. Blueback herring prefer spawning sites with fast currents and associated hard substrates, while alewives select a wider variety of sites, from standing water and oxbows to mid-river areas. Spawning occurs from April to July in the mid-Atlantic region; the onset and peak of alewife spawning precede those of blueback herring by 2 to 3 weeks. Larvae and juveniles remain in or near areas spawned before emigrating (as juveniles) to coastal areas between June and November of their first year. Emigration is apparently triggered by heavy runoff from rain and/or sharp decreases in water temperature. Adults overwinter offshore to depths of at least 110 m. Nantucket Shoals, Georges Bank, and the Gulf of Maine are important overwintering grounds. Commercial and limited recreational fisheries for these species occur; total U.S. landings in 1981 were 3,754 mt, while foreign landings were 13.9 mt. Some eggs can hatch at water temperatures between 7° and 29.5°C, but temperatures above 29.7°C are lethal. Larvae need temperatures greater than 10°C for proper development; upper lethal temperature is 31°C.

17. Document Analysis a. Descriptors

Rivers
Anadromous
Estuaries
Keywords. Fish
Growth (Physiology)
Feeding

b. Identifiers/Open-Ended Terms

Alewife
Alosa pseudoharengus
Blueback herring
Alosa aestivalis
Temperature requirement
Salinity requirements
Spawning

c. COSATI Field/Group

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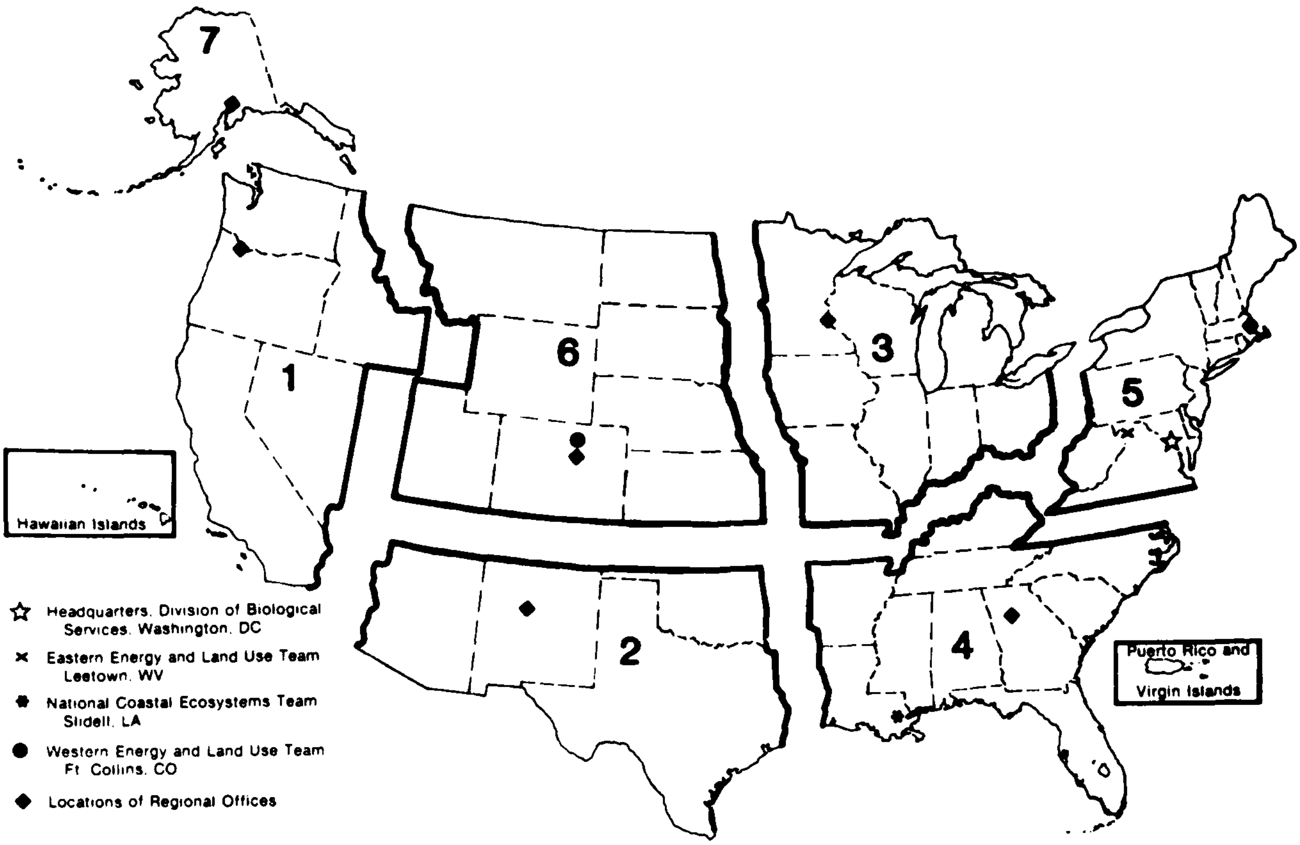


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